DAY THIRTY THREE

Polymers

Learning & Revision for the Day

- Classification of Polymers
- Polymerisation
- Some other Important Polymers

Polymers are defined as very large molecules having high molecular mass (10^3-10^7 u). These are formed by joining of repeating structural units, called monomers, on a large scale. The monomer units, are linked to each other by covalent bonds. The process of formation of polymer from respective monomers is called polymerisation.

Classification of Polymers

Some of the common classifications of polymers are :

(i) **On the Basis of Source**

- **Natural Polymers** These polymers are found in plants and animals, e.g. proteins, cellulose, starch, resins, rubber etc.
- Semi-synthetic Polymers These polymers are derived from natural polymers by chemical methods. e.g. cellulose acetate (rayon), cellulose nitrate etc.
- **Synthetic Polymers** These are man-made polymers. e.g. plastic (polythene), synthetic fibres, buna-S etc.

(ii) **On the Basis of Structure of Polymers**,

- **Linear Polymers** These polymers consist of long and straight chains, e.g. high density polythene, polyvinyl chloride etc.
- **Branched Chain Polymers** These polymers consist of linear chains with some branches, e.g. low density polythene.
- **Cross-linked or Network Polymers** These polymers contain strong covalent bonds between various linear polymer chains, e.g. bakelite, melamine etc.

(iii) **On the basis of Mode of Polymerisation**

- **Addition Polymers or Chain Growth Polymers** These are formed by the repeated addition reactions monomer molecules having multiple bonds, e.g. polythene, SBR.
- **Condensation Polymers or Step Growth Polymers** These are formed by repeated condensation process with elimination of small molecules like NH_3, H_2O etc. e.g. terylene, nylon-66, nylon-6 etc.

(iv) **On the Basis of Monomers**

- **Homopolymers** These are formed by polymerisation of single monomeric species. e.g. polythene, polypropene etc.

- **Copolymers** These are formed by polymerisation of two or more different monomer units.
  e.g. buna-S, buna-N etc.

NOTE Epoxy resins are used in making adhesives such as araldite etc. These are copolymer of epichlorohydrin and bisphenol-A.

(v) **On the Basis of Molecular Forces**

- **Elastomers** These are rubber-like solids with elastic properties. They have weak intermolecular forces. e.g. buna-S, buna-N, neoprene etc.
- **Fibres** These are the thread forming solids and have strong intermolecular hydrogen bonding. e.g. nylon-6,6, polyesters (terylene) etc.
- **Thermoplastic Polymers** These polymers possess intermolecular forces of attraction, intermediate between elastomers and fibres. e.g. polythene, polystyrene, polyvinyls etc.
- **Thermosetting Polymers** These polymers are cross-linked or heavily branched molecules e.g. bakelite, urea-formaldehyde resins etc.
  On long exposure to air and sunlight, thermoplastics become brittle due to the evaporation of plasticiser.

Polymerisation

The process or technique through which monomer units combine to give a polymer is known as polymerisation. The polymerisation reaction can't be controlled easily.

Following are the two principal methods through which monomers combine to give polymers.

1. Addition Polymerisation

It is the process in which molecules of same or different monomers combine together to give a polymer without the elimination of small molecules. It is also known as chain growth polymerisation.

This mode of polymerisation is observed in molecules having multiple bonds, mainly in $CH_2 = CHY$ type molecules (where, y may be —H, —X, —CO_2R, —CN etc.)

The addition or chain growth polymerisation can proceed by the following two mechanisms:

(i) By the formation of free radicals, i.e. free radical polymerisation.

(ii) By the formation of ionic species, i.e. ionic polymerisation (cationic or anionic).

- **Cationic addition polymerisation** is facilitated in monomers having electron releasing groups such as $-CH_3$, $-C_2H_5$ etc. Higher the stability of carbocation intermediate, more is the reactivity of monomer towards cationic addition polymerisation.
- Monomers containing electron withdrawing groups readily undergo **anionic addition polymerisation**.

2. Condensation Polymerisation

It is a combination of molecules of same or different monomers in a controlled stepwise manner with the elimination of small molecules such as water, ammonia, alcohol etc., as by-product.

The process is also known as **step growth polymerisation**

NOTE Other method of polymerisation is copolymerisation. In this method, two or more different monomer units polymerises to form a copolymer which contains multiple units of each monomer used, in the same polymeric chain.

Examples of Addition Homopolymers

(i) **Polymer** Polytetrafluoroethene (teflon)
Monomer Tetrafluoroethene ($CF_2=CF_2$)

Uses For making oil seals and gaskets, non-stick surface coated utensils.

(ii) **Polymer** Polythene (or polyethylene)
Monomer Ethene ($CH_2 = CH_2$)

Uses It is used for making containers, housewares, bottles,toys, electrical insulation etc.

(iii) **Polymer** Polyacrylonitrile (PAN)
Monomer Acrylonitrile ($CH_2=CHCN$)

Uses Substitute for wool in making commercial fibres such as orlon or acrilan (or polyproylene).

(iv) **Polymer** Polypropene (or polypropylene)
Monomer Propene

Uses In the manufacture of ropes, toys, pipes, fibres etc.

(v) **Polymer** Polystyrene
Monomer Styrene, ($CH_2=CH-C_6H_5$)

Uses As an insulator, wrapping material, manufacture of toys, radio and television cabinets, cups for hot drinks.

(vi) **Polymer** Polyvinyl chloride (PVC)
Monomer Vinyl chloride ($CH_2 = CH-Cl$)

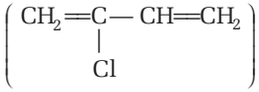
Plasticisers are added to plastics to make them soft and rubber like. e.g. addition of dibutyl phthalate to PVC makes it soft and rubber like.
Uses In the manufacture of rain coats, hand bags, vinyl flooring, water pipes etc.

(vii) **Polymer** Natural rubber or polyisoprene (linear polymer)
Monomer Isoprene (2-methyl-1, 3-butadiene)

$$\left(CH_2 = \underset{\displaystyle CH_3}{\overset{\displaystyle |}{C}} - CH = CH_2 \right)$$

Natural rubber can be stretched like a spring and exhibits elastic properties.

(viii) **Polymer** Neoprene (synthetic rubber)
Monomer Chloroprene (2-chloro-1,3-butadiene)



Uses In the manufacture of conveyor belts, gaskets and hoses.
Also, thiokol is a type of synthetic rubber. It is a copolymer of ethylene chloride and sodium tetrasulphide (Na_2S_4).

Examples of Addition Copolymers

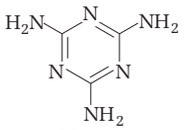
(i) **Polymer** Butadiene-styrene (Buna-S)
Monomers 1,3-butadiene ($CH_2{=}CH{-}CH{=}CH_2$) and styrene ($C_6H_5{-}CH{=}CH_2$).
Uses It is quite tough and is a good substitute for natural rubber. It is used for the manufacture of auto tyres, floor tiles, footwear components, cable insulation etc.

(ii) **Polymer** Buna-N
Monomers 1,3-butadiene ($CH_2{=}CH{-}CH{=}CH_2$) and acrylonitrile ($CH_2{=}CHCN$).
Uses It is resistant to the action of petrol, lubricating oil and organic solvents. It is used in making oil seals, tank lining etc.

Examples of Condensation Copolymers

(i) **Polymer** Phenol-formaldehyde polymer (bakelite)
Monomers Phenol (C_6H_5OH) and formaldehyde (HCHO).
Uses It is used for making combs, phonograph records, electrical switches and handles of various utensils.

(ii) **Polymer** Melamine-formaldehyde polymer
Monomer Formaldehyde (HCHO).



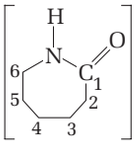
Melamine

Uses In the manufacture of unbreakable crockery.

(iii) **Polymer** Urea-formaldehyde resin
Monomers Urea (NH_2CONH_2) and formaldehyde (HCHO).
Uses For making unbreakable cups and laminated sheets.

Example of Condensation Homopolymers

Polymer Nylon-6 (perlon)
Monomer Caprolactam



In this reaction caprolactam is first hydrolysed with water to form *E*-amino caproic acid.

Natural and Synthetic Rubber

- Natural rubber is considered as a linear polymer of isoprene (2-methyl-1,3-butadiene) and is also called as *cis*-1,4-polyisoprene.
- It absorbs a large amount of water and has low tensile strength and elasticity. Due to which, vulcanisation of natural rubber is carried out.

Vulcanisation of Rubber

- To improve the undesired properties of natural raw rubber, vulcanisation of rubber is carried out. The process involves the heating of raw rubber with sulphur and appropriate additive (ZnO) at a temperature 373-414 K.
- Sulphur forms cross links at a reactive sites of double bonds and makes the rubber stiffened. Rubber made with 1-3% sulphur is soft and stretchy while rubber made with 3-10% S is more rigid (used in making tyre).

Synthetic Rubber

Synthetic rubber are homopolymers of 1,3-butadiene derivatives or copolymers of 1,3-butadiene or its derivatives with another unsaturated monomer.

Uses Nylon-6 is used for the manufacture of tyre cords, fabrics and ropes.

Some Other Important Polymers

1. **Polythene** is a polymer of ethene. Depending upon the conditions of temperature, pressure and nature of catalyst, polythene are of two types:

   (i) **Low Density Polythene** (LDP) is tough, flexible, transparent, chemically inert as well as poor conductor of electricity. It has moderate tensile strength but good tearing strength.

   It is used in the insulation of electricity carrying wires and manufacture of squeeze bottles, toys and flexible pipes.

   $$n(CH_2{=}CH_2) \xrightarrow[\text{1000 to 2000 atm}]{\text{350-570 K}} \underset{\text{LDP}}{-(CH_2-CH_2)_n-}$$
   (Traces of oxygen or a peroxide initiator)

   (ii) **High Density Polyethylene** (HDP) has high density due to close packing. It is also chemically inert and more tougher and harder.

   $$n(CH_2{=}CH_2) \xrightarrow[\text{6-7 atm}]{\text{333-343 K}} -(CH_2-CH_2)_n-$$
   (*Ziegler-Natta* catalyst)

2. **Polyamides** are polymers having amide linkages. Various types of polyamides are as follows:

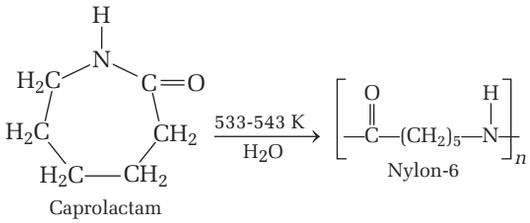
   - Nylon-6,6 is obtained by the condensation of adipic acid and hexamethylenediamine with the elimination of water molecule.

   $$\underset{\text{Hexamethylenediamine}}{nH_2N(CH_2)_6NH_2} + n\,HO-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-OH \quad \underset{\text{Adipic acid}}{}$$

   $$\xrightarrow[-nH_2O]{\text{553 K, high pressure}} \underset{\text{Nylon-6,6}}{-\left(N-(CH_2)_6-N-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}\right)_n-}$$

It is a linear polymer and has very high tensile strength. It shows good resistance to abrasion. It is usually fabricated into sheets. It is used in bristles for brushes and in textile industry.

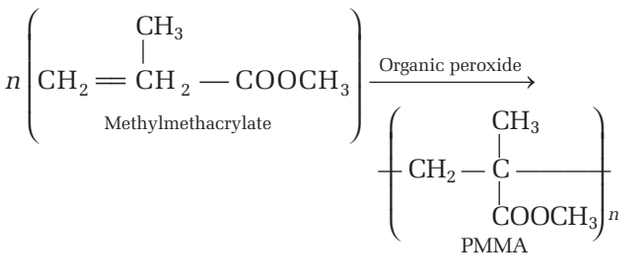
- Nylon-6 is obtained by heating caprolactum with water at a high temperature.



It is used for the manufacture of tyre cords, fabrics and ropes.

3. **Polyesters** are the polymers which contain an ester linkage. The examples are as follows:

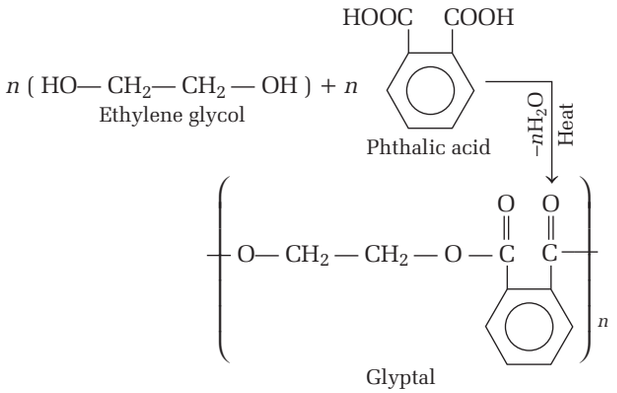
(i) **Polymethylmethacrylate** (PMMA) is prepared by the polymerisation of methylmethacrylate in the presence of suitable organic peroxide.



The polymer is known by several commercial names such as lucite, acrylite, plexiglass and perspex.

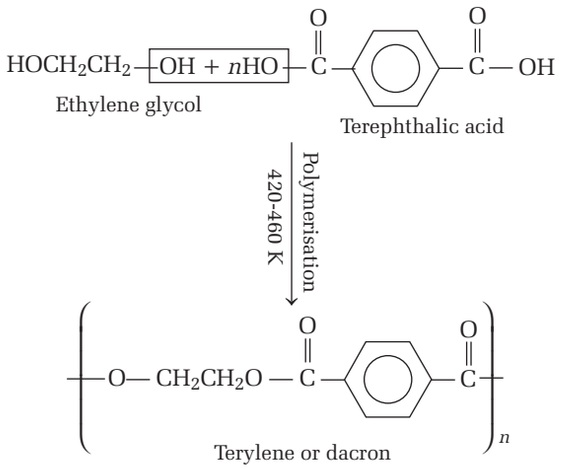
It is a hard and transparent polymer and is quite resistant to the effect of light, heat and ageing. It is used, in the manufacture of unbreakable lights, protective coatings and in making windows for aircrafts.

(ii) **Glyptal** is a polyester having cross-links. It is a thermosetting plastic. It is obtained by condensation of ethylene glycol or glycerol and phthalic acid.



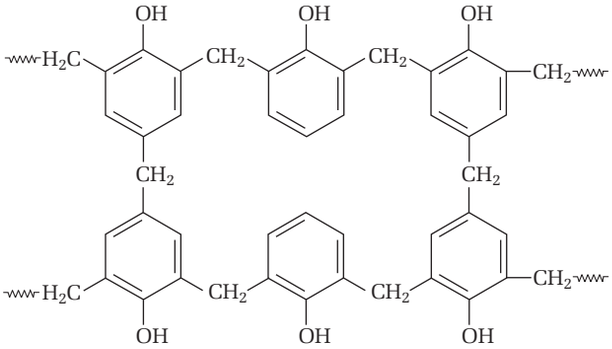
When its solution in a suitable solvent is evaporated, it leaves a tough but non-flexible film. Therefore, it is used in the manufacture of paints and lacquers.

(iii) **Terylene** (Dacron) is a condensation polymer of ethylene glycol and terephthalic acid. Polymerisation is carried out at 420 to 460 K in the presence of catalytic mixture of zinc acetate and antimony trioxide.



- Terylene is highly resistant to the action of chemicals and biological agents. Its fibres are quite strong and durable. It can also be blended with wool or cotton to obtain fabrics of desired composition.
- It is used in the manufacture of a variety of clothes such as terycot, terywool and terysilk as a result of blending with other yarns. It is also used for preparing magnetic recording tapes, conveyer belts, aprons for industrial workers etc.

4. **Bakelite** is a condensation polymer. The reaction starts with the initial formation of *o*- and *p*-hydroxy methylphenol derivatives which further reacts with phenol to form compounds having rings joined to each other through —CH_2 groups. The initial product formed is novolac which on heating with formaldehyde undergoes cross-linking to form infusible mass called bakelite. It is used in making combs,switches and handles.



NOTE **Biodegradable polymers** can be degraded by environmental processes like degradation by bacterial enzymes. e.g. poly-β-hydroxy butyrate-co-β-hydroxy valerate (PHBV), nylon-2-nylon-6.

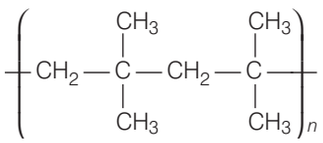
DAY PRACTICE SESSION 1

FOUNDATION QUESTIONS EXERCISE

1 Which of the following is not a semi-synthetic polymer?
(a) *cis*-polyisoprene (b) Cellulose nitrate
(c) Cellulose acetate (d) Vulcanised rubber

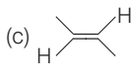
2 Which is an example of thermosetting polymer?
(a) Polythene (b) PVC
(c) Neoprene (d) Bakelite

3 The polymer containing strong intermolecular forces e.g. hydrogen bonding, is ➝ AIEEE 2010
(a) teflon (b) nylon-6,6
(c) polystyrene (d) natural rubber

4 

is a polymer having monomer units

(a)  (b) 

(c)  (d) 

5 Which one of the following can be used as a monomer in a polymerisation reaction?
(a) CH_3CH_2Cl (b) CH_3CH_2OH
(c) C_6H_6 (d) C_3H_6

6 The compound that inhibits the growth of polymer chain during vinyl polymerisation, is
(a) carbon tetrachloride (b) *p*-benzoquinone
(c) benzophenone (d) carbon dioxide

7 Which of the following monomers will react fastest in cationic polymerisation?

$CH_2=CH-CH_3$, $CH_2=C(CH_3)_2$, $CH_2=CH-CH(CH_3)_2$
(I) (II) (III)

(a) Only I (b) I, II and III
(c) Only II (d) I and III

8 The species which can best serve as an initiator for the cationic polymerisation is ➝ AIEEE 2012
(a) $LiAlH_4$ (b) HNO_3 (c) $AlCl_3$ (d) BaLi

9 Polymer formation from monomers starts by
(a) condensation reaction between monomers
(b) elimination reaction between monomers
(c) conversion of monomer to monomer ions by protons
(d) hydrolysis of monomers

10 Which of the following is fully fluorinated polymer?
(a) PVC (b) Thiokol
(c) Teflon (d) Neoprene

11 Which of the following contains isoprene units?
(a) Natural rubber (b) Nylon-6,6
(c) Polyethylene (d) Dacron

12 Which of the following monomers gives the polymer neoprene on polymerisation?
(a) $CH_2=CHCl$ (b) $CCl_2=CCl_2$
(c) $CH_2=CCl-CH=CH_2$ (d) $CF_2=CF_2$

13 Buna-N-asynthetic rubber is a copolymer of
(a) $H_2C=CH-\underset{\displaystyle Cl}{\overset{\displaystyle |}{C}}-CH_2$ and $H_2C=CH-CH=CH_2$
(b) $H_2C=CH-CH=CH_2$ and $H_5C_6-CH=CH_2$
(c) $H_2C=CH-CN$ and $H_2C=CH-CH=CH_2$
(d) $H_2C=CH-CN$ and $H_2C-\underset{\displaystyle CH_3}{\overset{\displaystyle |}{C}}=CH_2$

14 Synthetic human hair wigs are made from copolymerisation of vinyl chloride and acrylonitrile and is called
(a) PVC (b) polyacrylonitrile
(c) cellulose (d) dynel

15 Soft drink bottles and baby feeding bottles are generally made up of
(a) polyester (b) polyurea
(c) polyamide (d) polystyrene

16 Polymer obtained by condensation polymerisation is
(a) polythene (b) teflon
(c) phenol-formaldehyde (d) nitrile rubber

17 The catalyst used for the polymerisation of olefins is
(a) *Ziegler-Natta* catalyst (b) Wilkinson's catalyst
(c) Pd-catalyst (d) Zeolite

18 The catalyst used in the manufacture of polyethylene by *Ziegler* method is
(a) titanium tetrachloride and triphenyl aluminium
(b) titanium tetrachloride and triethyl aluminium
(c) titanium dioxide
(d) titanium isopropoxide

19 Which of the following statements about low density polythene is false? ➝ JEE Main 2016
(a) It is a poor conductor of electricity
(b) Its synthesis required dioxygen or a peroxide initiator as a catalyst
(c) It is used in the manufacture of buckets, dustbins etc
(d) Its synthesis requires high pressure

20 Which of the following polymers does not involve cross linkages?

(a) Melmac (b) Bakelite
(c) Polythene (d) Vulcanised rubber

21 Urethane is

(a) $H_2N-C\equiv N$ (b) $H_2N-\underset{\underset{O}{\|}}{C}-OH$

(c) $HO-C\equiv N$ (d) $H_2N-\underset{\underset{O}{\|}}{C}-OC_2H_5$

22 Which of the following is currently used as a tyre cord?

(a) Nylon-6
(b) Polyethylene
(c) Polypropylene
(d) Bakelite

23 Which one is classified as a condensation polymer?

➜ JEE Main 2014

(a) Dacron (b) Neoprene
(c) Teflon (d) Acrylonitrile

24 In which of the following polymers, empirical formula resembles with monomer?

(a) Bakelite (b) Teflon
(c) Nylon-6,6 (d) Dacron

25 Which of the following fibres is madeup of polyamides?

(a) Dacron (b) Orlon
(c) Nylon (d) Rayon

26 Which of the following polymer is a polyamide?

➜ JEE Main (Online) 2013

(a) Terylene (b) Nylon-6,6
(c) Rubber (d) Vulcanised rubber

27 The formation of which of the following polymers involves hydrolysis reaction? ➜ JEE Main 2017

(a) Nylon-6 (b) Bakelite
(c) Nylon-6, 6 (d) Terylene

28 Bakelite is obtained from phenol by reaction with

➜ AIEEE 2011, 08

(a) HCHO (b) $(CH_2OH)_2$
(c) CH_3CHO (d) CH_3COCH_3

29 Which of the following contains ester linkage?

(a) Nylon-6,6 (b) Dacron
(c) Bakelite (d) PVC

30 Polymer used in bullet proof glass is

(a) PMMA
(b) lexan
(c) nomex
(d) kevlar

31 The polymer used for optical lenses is

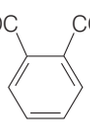
➜ JEE Main (Online) 2013

(a) polypropylene (b) polyvinyl chloride
(c) polythene (d) polymethyl methacrylate

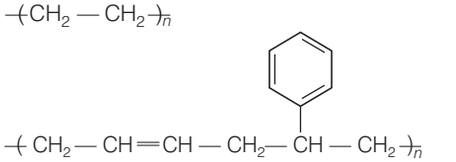
32 Which of the following polymer is used in the manufacture of paints and lacquers? ➜ JEE Main 2015

(a) Bakelite (b) Glyptal
(c) Polypropene (d) Polyvinyl chloride

33 In which of the following polymers, ethylene glycol is one of the monomer units?

(a) $-\{OCH_2-CH_2OOC$  $CO-\}_n$

(b) $-\{CH_2-CH_2-\}_n$

(c) 

(d) $-\{O-\underset{\underset{CH_3}{|}}{CH}-CH_2-\underset{\underset{O}{\|}}{C}-O-\underset{\underset{CH_2CH_3}{|}}{CH}-CH_2-\underset{\underset{O}{\|}}{C}-\}_n$

34 Terylene is a condensation polymer of ethylene glycol and

(a) benzoic acid (b) phthalic acid
(c) salicylic acid (d) terephthalic acid

35 Which of the following is not correctly matched?

(a) Neoprene : $\left(-CH_2-\underset{\underset{Cl}{|}}{C}=CH-CH_2-\right)_n$

(b) Nylon-6,6 : $\left(-NH-(CH_2)_6-NH-CO-(CH_2)_4-\underset{\underset{O}{\|}}{C}-\right)_n$

(c) Terylene : $\left(-O-CH_2CH_2-\underset{\underset{O}{\|}}{C}-C_6H_4-\underset{\underset{O}{\|}}{C}-\right)$

(d) PMMA : $\left(-CH_2-\underset{\underset{COOCH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-\right)_n$

36 Which of the following polymer is biodegradable?

(a) $-\{CH_2-\underset{\underset{Cl}{|}}{C}=CH-CH_2-\}_n$

(b) $-\{-CH_2-CH=CH-CH_2-CH_2-CH-\}_n$

(c) $-\{O-\underset{\underset{CH_3}{|}}{CH}-CH_2-\underset{\underset{O}{\|}}{C}-O-\underset{\underset{CH_2\ CH_3}{|}}{CH}-CH_2-\underset{\underset{O}{\|}}{C}-\}_n$

(d) $\left(-\overset{\overset{H}{|}}{N}-(CH_2)_6-\overset{\overset{H}{|}}{N}-\underset{\underset{O}{\|}}{C}-(CH_2)_4-\underset{\underset{O}{\|}}{C}-\right)_n$

37 An example of biopolymer is

(a) teflon (b) neoprene
(c) nylon-6,6 (d) DNA

38 Match the Columns and choose the correct option.

	Column I		Column II
A.	Nylon-6	1.	Polyvinyl chloride
B.	PVC	2.	Polyacrylonitrile
C.	Acrilan	3.	Polycaprolactum
D.	Natural rubber	4.	*cis*-polyisoprene

Codes

	A	B	C	D		A	B	C	D
(a)	3	1	2	4	(b)	1	2	4	3
(c)	4	1	2	3	(d)	1	4	3	2

39 Number average molecular mass, $\overline{M}_n$ and weight average molecular mass ($\overline{M}_w$) of synthetic polymers are related as

(a) $\overline{M}_n = (\overline{M}_w)^{1/2}$ (b) $\overline{M}_n = \overline{M}_w$

(c) $\overline{M}_w > \overline{M}_n$ (d) $\overline{M}_w < \overline{M}_n$

Direction (Q. Nos 40 and 41) *In the following questions, assertion followed by reason is given. Choose the correct answer out of the following choices.*

(a) Both A and R are true and R is correct explanation of A

(b) Both A and R are true but R is not correct explanation of A

(c) A is true but R is false

(d) Both A and R are false

40 **Assertion** (A) Olefinic monomers undergo addition polymerisation.

Reason (R) Polymerisation of vinyl chloride is initiated by peroxides/persulphates.

41 **Assertion** (A) Most of the synthetic polymers are biodegradable.

Reason (R) Polymerisation process induces toxic character in organic molecules.

Direction (Q. Nos. 42-44) *Each of these questions contains two statements : Statement* I *and Statement* II. *Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below :*

(a) Statement I is true, Statement II is true; Statement II is a correct explanation for Statement I

(b) Statement I is true, Statement II is true; Statement II is not a correct explanation for Statement I

(c) Statement I is true; Statement II is false

(d) Statement I is false; Statement II is true

42 **Statement I** Acrilan is a homopolymer.

Statement II Its another name is PAN.

43 **Statement I** Buna-S, buna-N and neoprene rubber are elastomers.

Statement II Polymer chains are held together by weak van der Waals' forces.

44 **Statement I** Phenol-formaldehyde polymer (bakelite) is a thermosetting polymer.

Statement II Bakelite polymer is cross-linked or heavily branched molecules which on heating undergoes extensive cross linking.

DAY PRACTICE SESSION 2

PROGRESSIVE QUESTIONS EXERCISE

1 The chemical name of melamine is

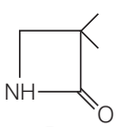
(a) 2, 4- diamino- 1, 3, 5 - triazine

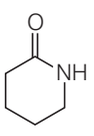
(b) 2- amino -1, 3, 5 - triazine

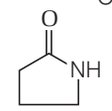
(c) 2, 4, 6 - triamino –1, 3, 5 - triazine

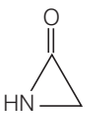
(d) 1, 3, 5 - triamino –2, 4, 6 - triazine

2 Lactum from which nylon-4 is synthesised is

(a) 

(b) 

(c) 

(d) 

3 If N_1, N_2, N_3..... are the number of molecules with moelcular masses M_1, M_2, M_3..... respectively then mass average molar mass is expressed as

(a) $\frac{\Sigma N_i M_i^2}{\Sigma N_i M_i}$ (b) $\frac{\Sigma N_i M_i^2}{\Sigma N_i}$

(c) $\frac{\Sigma M_i^2}{\Sigma N_i}$ (d) $\frac{\Sigma N_i M_i^2}{\Sigma M_i}$

4 In the vulcanisation of rubber

(a) sulphur reacts to form a new compound

(b) sulphur cross links are introduced

(c) sulphur forms a very thin protective layer over rubber

(d) All given statements are correct

5 Free radical polymerisation requires a free radical initiator. The most commonly used free radical initiator is

(a) Ph — CO — O — O—COPh, benzoylperoxide

(b) $(CH_3)_3C-O-O-C(CH_3)_3$, *tert*-butylperoxide

(c) $C_6H_5-N=N-C_6H_5 \longrightarrow O$, azoxybenzene

(d) CH_2N_2, diazomethane

6 Which of the following is true for polypropylene?

(a) Propylene, condensation polymer

(b) Propylene, addition polymer

(c) propylene, anionic polymers

(d) Propylene, cationic polymers

7 Which of the following sets contain only copolymers?

(a) SBR, glyptal, nylon- 6, 6

(b) Polythene, polyester, PVC

(c) Nylon-6, butyl rubber, neoprene

(d) Melemac, bakelite, teflon

8 A polymeric sample consist of 10% by weight of a macromolecule of molecular weight 10000 and 90% by weight of a macromolecule with molecular weight 100000, then its weight average molecular mass will be

(a) 52000 (b) 85000

(c) 91000 (d) 89000

9 Natural rubber is not used in making footwear for polar regions because

(a) natural rubber becomes soft at temperature lower than 10° C

(b) natural rubber becomes brittle at temperature lower than 10°C

(c) natural rubber melts at temperature lower than 10°C

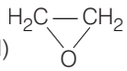
(d) natural rubber becomes stronger at temperature lower then 10°C

10 Arrange the following in increasing order of their intermolecular forces; Nylon 6,6 (I), Buna-S (II), Polythene (III)

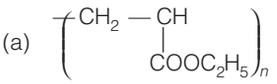
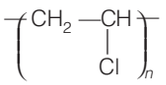
(a) II, I, III (b) III, II, I (c) I, II, III (d) II, III, I

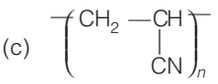
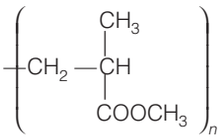
11 A compound (*A*) when reacts with $Ba(CN)_2$ and HCN, addition takes place and cyano derivative (*B*) is formed. On heating compound (*B*) in the presence of $FeSO_4$ and peroxide, orlon polymer is obtained. Compound (*A*) is

(a) $CH_2=CHCN$ (b) $CH\equiv CH$

(c) $CH_2=CHCl$ (d) 

12 Orlon is a hard, horny and a high melting material. Which of the following represents its structure?

(a)  (b) 

(c)  (d) 

13 Which of the following pair of monomers form biodegradable polymers?

I. 3-hydroxybutanoic acid + 3-hydroxypentanoic acid

II. Glycine + amino caproic acid

III. Ethylene glycol + phthalic acid

IV. Caprolactam

(a) I, II only (b) II, III only

(c) I, II and III (d) II, III and IV

14 A polymeric sample in which 30% molecules have a molecular mass 20,000, 40% have 30,000 and the rest 30% have 60,000. The $(\overline{M}n)$ and $(\overline{M}w)$ of this sample are,

(a) 36,000, 43,333 (b) 43,333, 36000

(c) 72,000, 86,666 (d) 86,666, 72000

15 Polyethylene is obtained from calcium carbide as

$$CaC_2 + 2H_2O \longrightarrow Ca(OH)_2 + C_2H_2$$

$$C_2H_2 + H_2 \longrightarrow C_2H_4$$

$$nC_2H_4 \longrightarrow \text{-}(CH_2-CH_2)\text{-}_n$$

Therefore, the amount of polyethylene obtained from 64 kg CaC_2 is

(a) 7 kg (b) 14 kg (c) 21 kg (d) 28 kg

ANSWERS

SESSION 1

1 (a)	**2** (d)	**3** (b)	**4** (a)	**5** (d)	**6** (b)	**7** (c)	**8** (c)	**9** (a)	**10** (c)
11 (a)	**12** (c)	**13** (c)	**14** (d)	**15** (d)	**16** (c)	**17** (a)	**18** (a)	**19** (c)	**20** (c)
21 (d)	**22** (a)	**23** (a)	**24** (c)	**25** (c)	**26** (b)	**27** (a)	**28** (a)	**29** (b)	**30** (b)
31 (d)	**32** (b)	**33** (a)	**34** (d)	**35** (c)	**36** (c)	**37** (d)	**38** (a)	**39** (c)	**40** (b)
41 (d)	**42** (b)	**43** (a)	**44** (a)						

SESSION 2

1 (c)	**2** (c)	**3** (a)	**4** (b)	**5** (a)	**6** (b)	**7** (a)	**8** (c)	**9** (b)	**10** (d)
11 (b)	**12** (c)	**13** (a)	**14** (a)	**15** (d)					

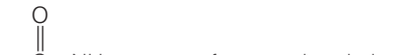
Hints and Explanations

SESSION 1

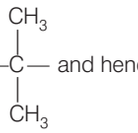
1 *cis*-polyisoprene is a natural polymer.

2 Bakelite is a thermosetting polymer.

3 In nylon-6,6 hydrogen bonds are formed between



group of successive chains.

4 The repeating structural unit is  and hence, the monomer is isobutylene, .

5 Only olefins (here, C_3H_6) and dienes undergo addition polymerisation.

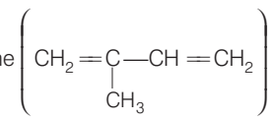
6 Certain amines, phenols and quinones are used to inhibit the growth of polymer chain.

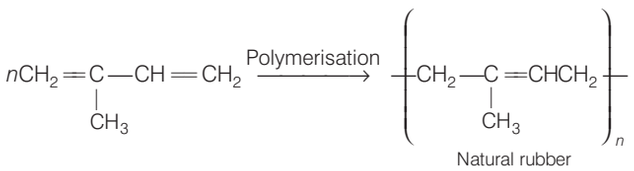
7 $CH_2=C(CH_3)_2$ will react faster than the other two because of the formation of a tertiary carbocation (stable) during polymerisation.

8 Electron-deficient species (Lewis acid like $AlCl_3$) is used as an initiator for cationic polymerisation.

9 Polymers are obtained by the condensation reaction between monomers.

10 Teflon is $-(CF_2-CF_2)_n-$. Thus, it is fully fluorinated polymer.

11 Isoprene  is the monomer of natural rubber.



Natural rubber

12 Chloroprene ($CH_2=CCl-CH=CH_2$) is the monomer of neoprene.

13 Buna-N actually abbreviated as NBR. BR represents butadiene rubber, N represents nitrile (acrylonitrile).
Thus, buna-N is a copolymer of 1, 3-butadiene and acrylonitrile and it usually polymerises in the presence of sodium.

14 Dynel is a copolymer of vinyl chloride and acrylonitrile.

15 Polystyrene is used for making soft drink bottles and baby feeding bottles.

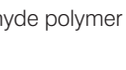
16 Phenol-formaldehyde polymer is obtained by condensation polymerisation.

17 *Ziegler-Natta* catalyst is used for the polymerisation of olefins.

18 Titanium tetrachloride + triethyl aluminium.

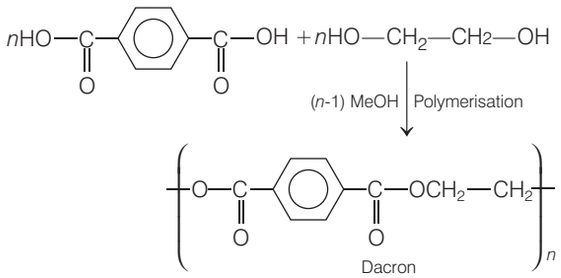
19 High density polythene is used in the manufacture of buckets, dustbins etc.

20 Polythene does not involve cross-linkages.

21 Urethane is  .

22 Nylon -6 is used as tyre cord.

23 Dacron is a condensation polymer of ethylene glycol and terepthalic acid.

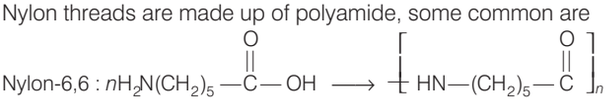


Dacron

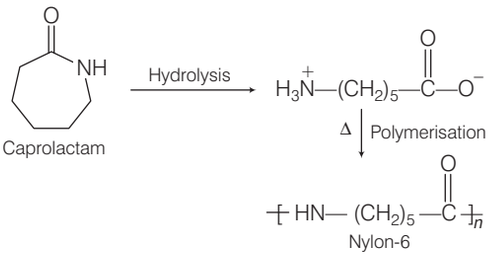
24 Nylon-6,6 is a polyamide of hexamethylene diamine $(CH_2)_6(NH_2)_2$ and adipic acid $(CH_2)_4(COOH)_2$. Each reactant has six carbon chain, hence trade code (6, 6) is used.

25 Nylon fibres is madeup of polyamides.

26 Nylon threads are made up of polyamide, some common are



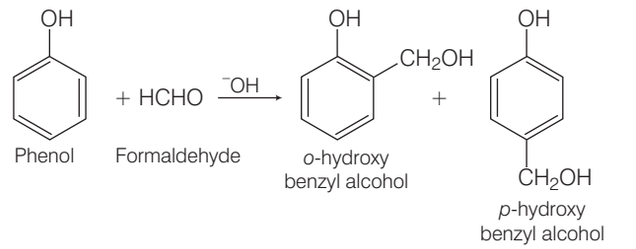
27 Nylon-6 or perlon is prepared by polymerisation of amino caproic acid at high temperature. Caprolactum is first hydrolysed with water to form amino acid which on heating undergoes polymerisation to give nylon-6.

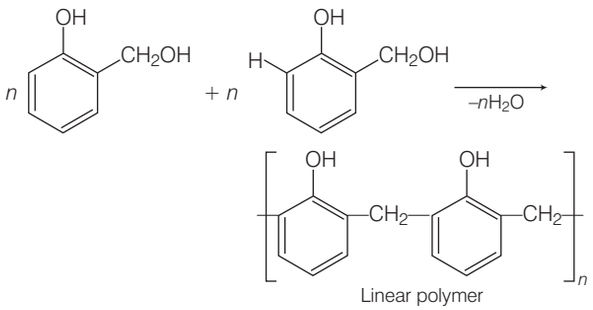


Caprolactam

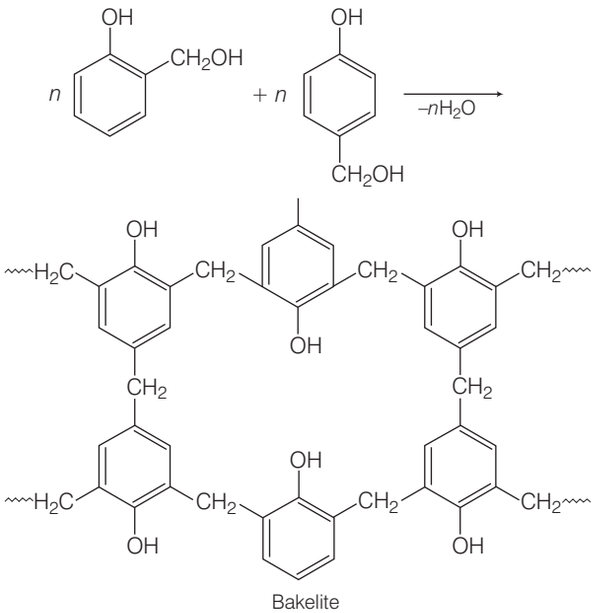
Nylon-6

28 Bakelite is obtained from phenol by reacting, with HCHO in acidic or alkaline medium.





Here, both the isomers again undergo condensation polymerisation and a highly cross-linked polymer, called 'bakelite' is obtained.



29 When a diacid is condensed with diol, the polymer obtained contains ester linkage, e.g. dacron.

30 Lexan or polycarbonate (polyester) is a condensation copolymer which is used in making bullet proof glass and safety helmets.

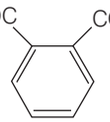
31 Polymethyl methacrylate (PMMA or plexi glass) is used as a substitute of glass. Hence, used to prepare optical lenses.

32. (a) Bakelite is used for making gears, protective coating and electrical fittings.

(b) Glyptal is used in the manufacture of paints and lacquers.

(c) Polypropene is used in the manufacture of textile, packaging materials etc.

(d) Poly vinylchloride (PVC) is used in the manufacture of rain coats,hand bags, leather clothes etc.

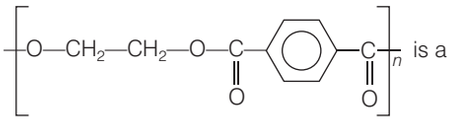
33 —(OCH$_2$—CH$_2$OOC  CO-)$_n$ is the strucutre of glyptal whose monomers are are ethylene glycol and phthalic acid.

34 nHOOC—C$_6$H$_4$—COOH + nHOCH$_2$—CH$_2$OH $\xrightarrow{-H_2O}$

Terephthalic acid; Ethylene glycol

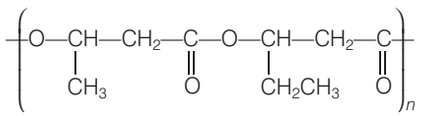
—(OCC$_6$H$_4$COOCH$_2$CH$_2$—O-)$_n$

Terylene or dacron

35 Terylene  is a

polymer of ethylene glycol and terephthalic acid. Thus, it is not correctly matched.

36 PHBV is a biodegradable polymer. Its structure is



37 DNA is an example of biopolymer.

38 A ⟶ 3; B ⟶ 1; C ⟶ 2; D ⟶ 4

39 $$PDI = \frac{\overline{M}_w}{\overline{M}_n}$$

For synthetic polymer, PDI > 1

$\therefore \quad \overline{M}_w > \overline{M}_n$

40 **Correct explanation** Due to the presence of double bonds,a large number of olefin molecules simply add to form a high molecular mass molecule.

Thus, both assertion and reason are correct but reason is not the correct explanation of the assertion.

41 **Correct reason** Most of the synthetic polymers are not degraded by enzymatic hydrolysis and environmental oxidation.

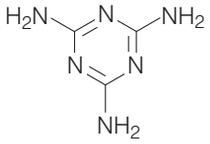
42 Both statements are correct but II is not a correct explanation for I. Acrilan is a homopolymer, i.e. it is formed by polymerisation of single monomeric species.

43 Buna-S, buna-N and neoprene rubber are elastomers. Here, polymer chains are held together by weak van der Waal's forces.

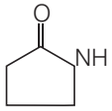
44 Phenol-formaldehyde (bakelite) polymer is a thermosetting polymer. It is a cross linked polymer which on heating undergoes extensive cross linking.

SESSION 2

1 Chemical name of melamine is 2, 4, 6-triamino-1, 3, 5-triazine



2 Lactum is used in the synthesis of nylon-4.



3 The expression for mass-average molar mass is

$$\overline{M}_w = \frac{\sum N_i M i^2}{\sum N_i M_i}$$

4 In vulcanisation of rubber, sulphur forms cross links at the reactive sites of double bond and makes the rubber stiffened.

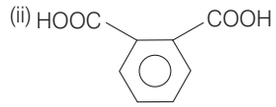
5 Most commonly used free radicals generator/initiator are organic and inorganic peroxides like benzoyl peroxide $(PhCOO)_2$.

6 Polypropylene is a thermoplastic addition polymer, formed by monomeric unit, propylene (propene).

7 **Buna-S** (SBR) Monomers- (i) $CH_2=CH-CH=CH_2$ (Buta -1, 3-diene)

(ii) $CH(C_6H_5)=CH_2$ (Styrene)

Glyptal Monomers (i) $HO-CH_2-CH_2-OH$ (Ethylene glycol)

(ii)  (Pthalic acid)

Nylon-6, 6 Monomers (i) $HO-C(=O)-(CH_2)_4-C(=O)-OH$ Adipic acid

(ii) $H_2N-(CH_2)_6-NH_2$ Hexamethylene diamine

8 $\overline{M}_W = \dfrac{m_1M_1 + m_2M_2 + m_3M_3 + ...}{m_1 + m_2 + m_3 +}$

$$\overline{M}_W = \frac{0.1\times 10000 + 0.9\times 100000}{(0.1 + 0.9)} = 91000$$

9 Natural rubber becomes brittle at temperature lower than 10°C and therefore is not used for making footwears for polar regions.

10 Buna-S is an elastomer, thus has weakest intermolecular forces. Nylon-6,6, is a fibre, thus has strong intermolecular forces like H-bonding. Polythene is a thermoplastic polymers, thus the intermolecular forces present in polythene are in between elastomer and fibres. Thus, the order of intermolecular forces of these polymers is:

Buna-S < Polythene < Nylon-6,6.

11 $CH\equiv CH \xrightarrow[Ba(CN)_2]{HCN} \underset{(B)}{CH_2=CHCN} \xrightarrow[FeSO_4,\ peroxide]{Polymerisation} \underset{Orlon}{-[CH_2-CH(CN)]_n-}$

(A) = Vinyl cyanide

12 Orlon is a polymer of vinyl cyanide or acrylonitrile $(CH_2=CHCN)$

13 Monomers 3-hydroxy, butanoic acid and 3-hydroxypentanoic acid react each other and form biodegradable polymer PHBV. Glycine and amino caproic acid also react to form biodegradable polymers nylon-2-nylon-6.

14 $\overline{M}_n = \dfrac{(30\times 20000) + (40\times 30000) + (30\times 60000)}{(30 + 40 + 30)}$

$= 36000$

$$\overline{M}_w = \frac{30(20000)^2 + 40(30000)^2 + 30(60000)^2}{30\times 20000 + 40\times 30000 + 30\times 60000}$$

$= 43333$

15 Moles of $CaC_2 = \dfrac{64\times 10^3}{64} \simeq 1\times 10^3$ g

$\therefore$ From the balanced chemical equation,

Moles of C_2H_4 = moles of C_2H_2

= moles of $CaC_2 = 1\times 10^3$

$\therefore$ Moles of polythene $= \dfrac{1}{n}\times 1\times 10^3$

$\therefore$ Weight of polythene $= \dfrac{1}{n}\times 1\times 28\, n$ kg = 28 kg